

# Muon Phase-II Upgrade R&D



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# Scope of the Phase II Muon Upgrade



LHCC-G-166: <https://cds.cern.ch/record/2055248/>

Phase II upgrades to the muon spectrometer are required to handle increased rates and fakes associated with HL-LHC luminosities ( $7 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$ ) and the new ATLAS wide L0/L1 trigger system

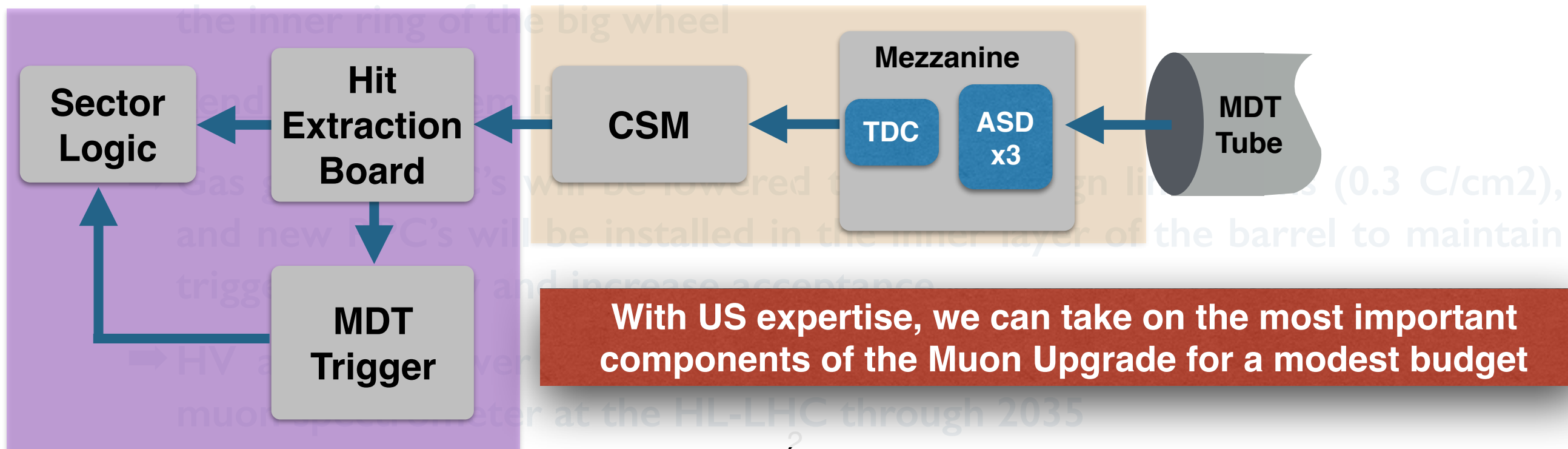
➔ To cope with high rates, the readout of the MDT system must be replaced, as well as the barrel (RPC) and end-cap (TGC) triggering system

➔ To reduce fakes

➔  $p_T$  selectivity of tracks for the trigger will be improved by integrating MDT information into the L1 (possibly L0) trigger

USA15

On chamber electronics



With US expertise, we can take on the most important components of the Muon Upgrade for a modest budget

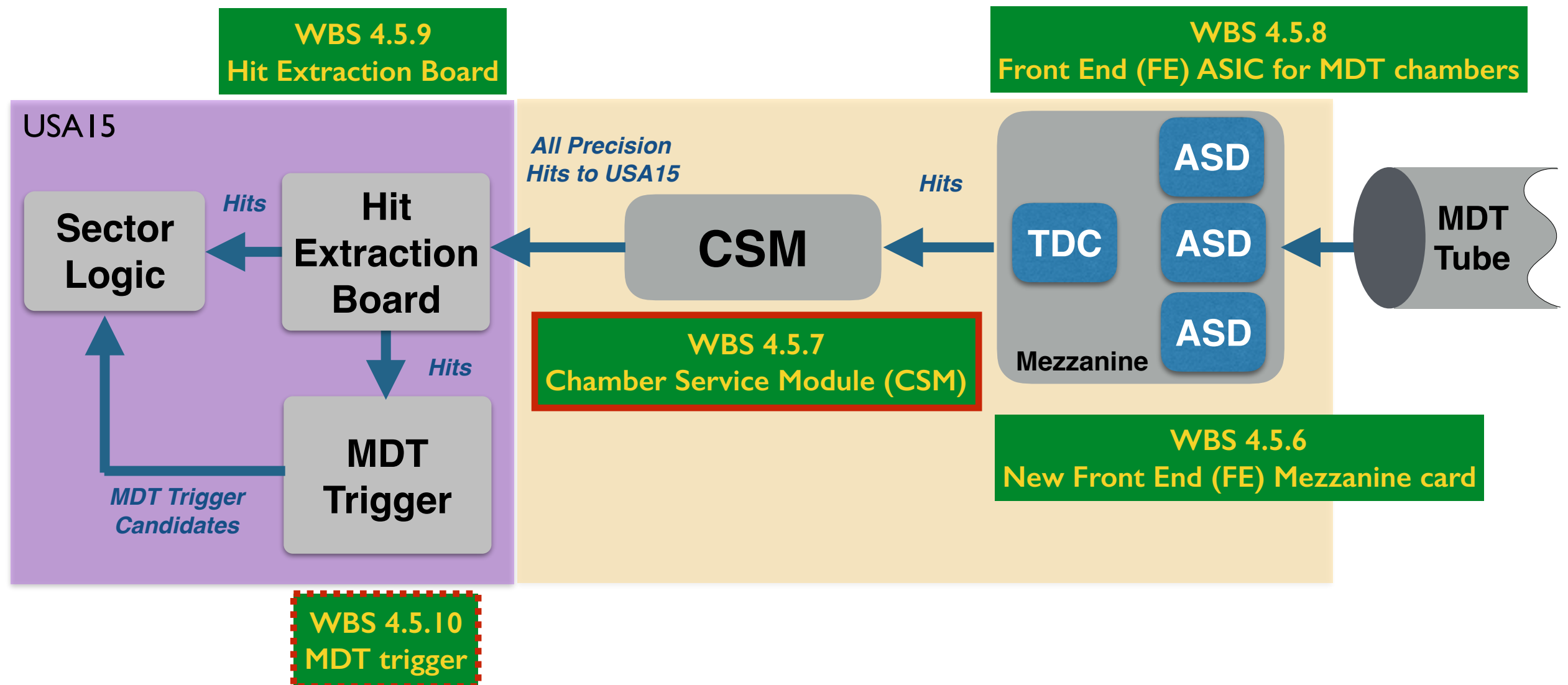


# Phase II MDT System

## Baseline trigger requirements for Phase-II

- ➔ L0 trigger accept rate up to 1 MHz within 6  $\mu$ s latency
- ➔ L1 trigger accept rate up to 400 kHz within 30  $\mu$ s latency
- ➔ MDT data integrated into L1 (maybe L0) trigger to sharpen muon  $p_T$  trigger

Requires the replacement of the mezzanine cards and CSM boards



Currently Funded

To be funded with RBT in FY16

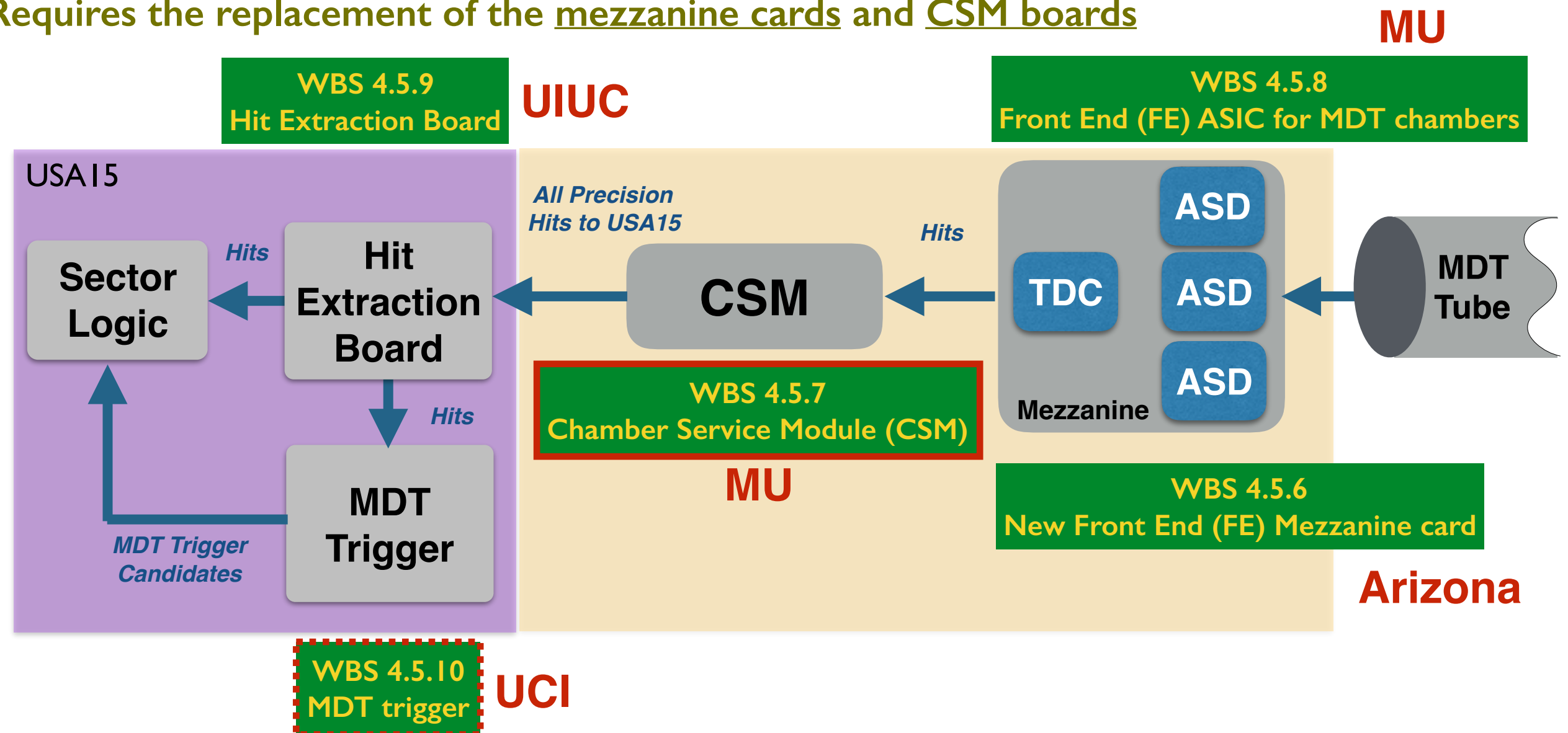


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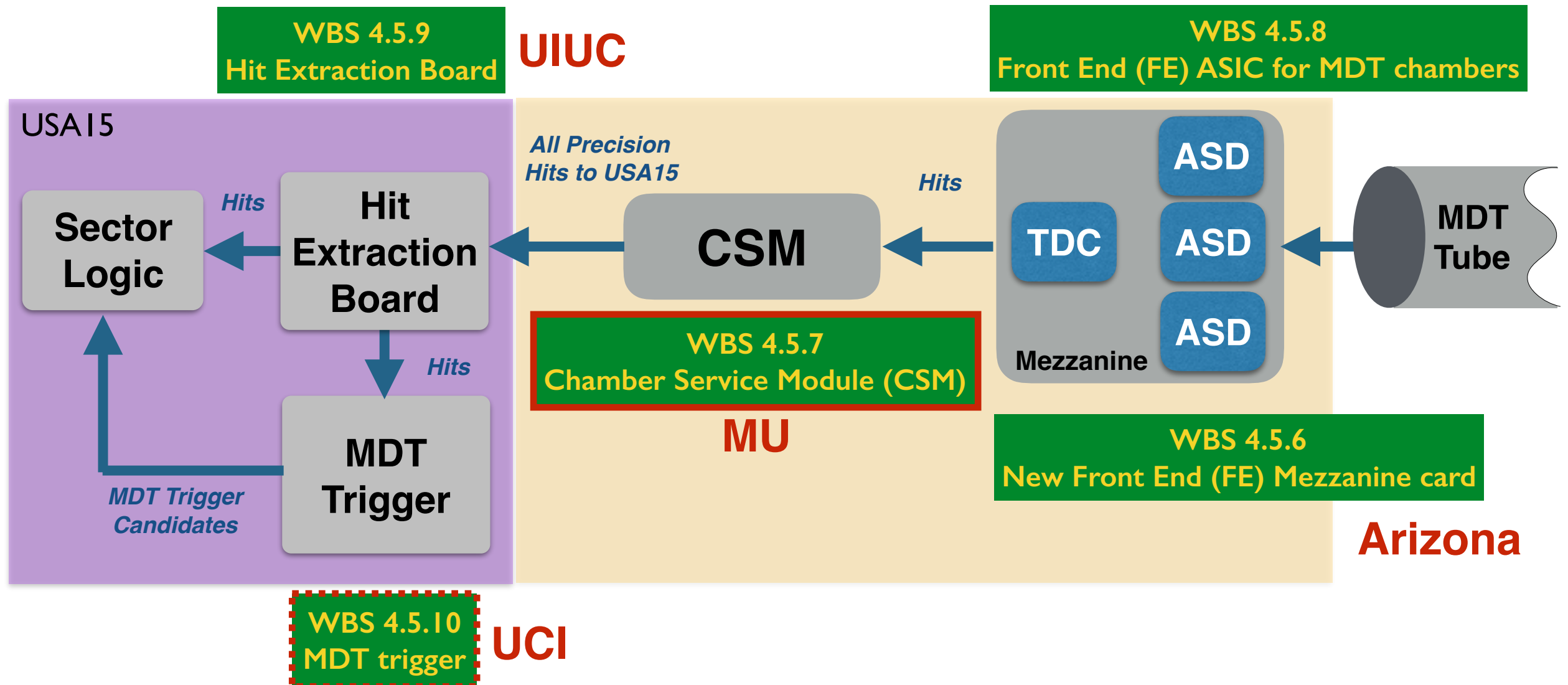
## Baseline trigger requirements for Phase-II

VMM used in Phase I could be modified to perform both TDC and ASD functionality for the Phase II MDT readout system

*BNL currently studying this possibility*

trigger

**MU/BNL**



Currently Funded

To be funded with RBT in FY16



## Proposed activities FY16

- Development of full simulation from mezzanine to CSM
- Development of several high-level designs and simulate their performance
- Current System Studies and Hardware Testing

## Proposed activities FY17/18

- Design and Simulation of the CSM
- Prototype Development of the CSM

## Proposed activities FY19

- Cooling design and power consumption
- Radiation testing
- Prototype v2
- Full system integration testing



# R&D Budget - Michigan CSM



## WBS 4.5.7: CSM

	R&D									
Items	FY15 FTE	\$/hr	FY16 FTE	\$/hr	FY17 FTE	\$/hr	FY18 FTE	\$/hr	FY19 FTE	\$/hr
	-		1.00		2.00		3.00		4.00	
Jr. E Engineer (Xueye Hu)	0.20	52.99	0.60	54.58	1.00	56.22	1.00	57.90	1.00	59.64
Proj. Scientist (Dan Levin)	-	85.55	0.30	88.12	0.35	90.76	0.35	93.48	0.35	96.29
Staff Scientist (Claudio Feretti)	-	52.02	0.25	53.58	0.25	55.19	0.25	56.84	0.25	58.55
EE student (Xiangting Meng)	1.00	32.47	1.00	33.44	1.00	34.45	1.00	35.48	1.00	36.55
				(k\$)		(k\$)		(k\$)		(k\$)
Total Personel	1.20	76.49	2.15	188.30	2.60	241.94	2.60	249.20	2.60	256.67
Prototypes/Materials/Softwares		-		-		5.00		10.00		10.00
Travel		7.00		3.00		3.00		3.00		3.00
Radiation Testing Feed		8.00						8.00		
Final Production										
Shipping										
<b>Total</b>		<b>91.49</b>		<b>191.30</b>		<b>249.94</b>		<b>270.20</b>		<b>269.67</b>

**Fully Funded**  
w/ RBT

# Plans & Milestones for FY17-19 - Michigan ASIC TDC



- Japan currently working on a radiation hard FPGA TDC.
- Another alternative is an ASIC TDC

## Proposed activities FY17

- Investigating ASIC TDC (alternative to VMM and FPGA-based TDC)

## Proposed activities FY18

- Begin design for ASIC TDC prototype v1

## Proposed activities FY19

- Possibly packaging and testing ASIC prototype

## WBS 4.5.8: FE ASIC TDC

	R&D					
Items	FY17 FTE	\$/hr	FY18 FTE	\$/hr	FY19 FTE	\$/hr
Jr. E Engineer (Jinhong Wang)	2.00		3.00		4.00	
	0.20	56.22	1.00	57.90	1.00	59.64
	-					
		(k\$)		(k\$)		(k\$)
Total Personel	0.20	19.97	1.00	102.84	1.00	105.92
Prototypes/Materials/Softwares		-		80.00		-
Travel		-		-		-
Radiation Testing Feed				-		
Final Production						
Shipping						
<b>Total</b>		<b>19.97</b>		<b>182.84</b>		<b>105.92</b>



- VMM being developed for the NSW makes a very attractive alternative for a front end that includes time digitization
  - Small modifications needed: programmable dead time and faster shaping
  - Lower cost than developing a new FE
- Big Wheel TGC replacement with sTGC will need VMM front ends which BNL will have to provide

## Justification FY18 - FY19

- 1.5 FTE design engineer (\$220k/yr) to perform necessary modifications to current VMM for MDT.
  - Implement any changed that may be needed for the Big Wheel sTGC
- Technical student for testing
- Travel

## WBS 4.5.8: FE ASIC

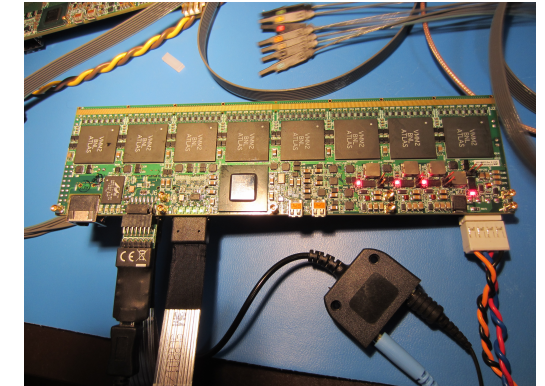
Items	R&D			
	FY18 FTE	\$/hr	FY19 FTE	\$/hr
	3.00		4.00	
Project Scientist	0.50	118.85	1.00	122.41
Technical student 1	1.00	27.96	1.00	28.80
Technical student 2	-	27.96	1.00	28.80
		(k\$)		(k\$)
Total Personel	1.50	155.20	3.00	319.71
Prototypes/Materials/Softwares		-		-
Travel		6.00		9.27
Radiation Testing Feed		-		
Final Production				
Shipping				
<b>Total</b>		<b>161.20</b>		<b>328.98</b>

# Plans & Milestones for FY17-18 - Arizona Mezz



## Group expertise from Phase-I Upgrade (NSW):

- Designing & testing 4100 front end boards for the NSW Micromegas chambers
  - FE board uses 8 BNL VMM ASICs for analog shaping and digitization and 2 custom ASICs.
  - Board must function in challenging radiation and magnetic field environment
- Successfully built FE boards demonstrator that will be used in the Micromegas production factories



## Group expertise translates well to the electronics needed for the MDTs Phase-II upgrade

### Proposed activities FY17/FY18

- Begin setting up and doing initial design work and infrastructure setup for mezzanine board

### Proposed activities FY19

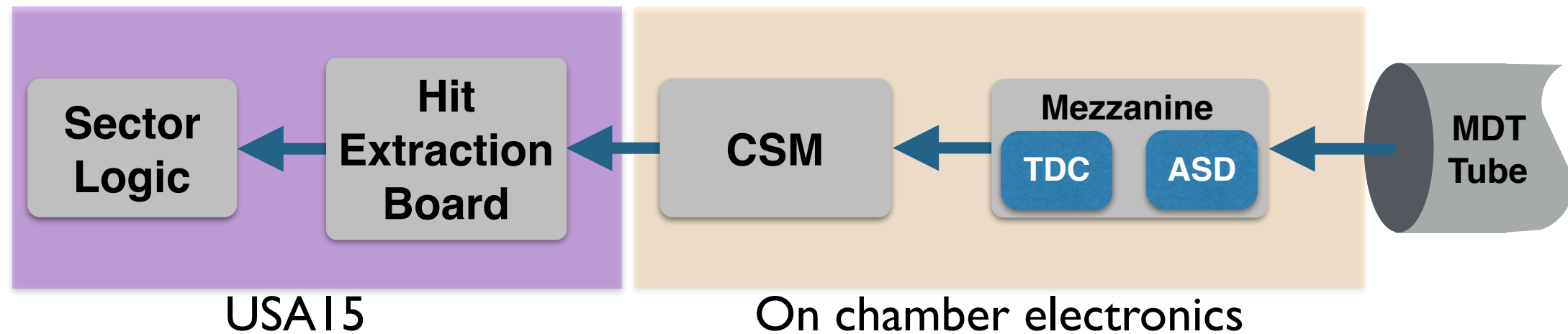
- Make a simple conceptual prototype that utilizes one ASIC (simple board for lab testing by Arizona and others)

# R&D Budget - Arizona - Mezzanine



## WBS 4.5.6 Mezzanine

	R&D					
Items	FY17 FTE	\$/hr	FY18 FTE	\$/hr	FY19 FTE	\$/hr
	2.00		3.00		4.00	
Electrical Engineer 1	0.21	96.31	0.14	99.20	0.46	102.18
Electrical Engineer 2	-	52.55	-	54.13	-	55.75
Electrical Engineer 3	0.08	147.04	-	151.45	-	156.00
Engineer Associate 1	0.25	37.51	0.12	38.64	0.40	39.80
Engineer Associate 2	-	37.51		38.64		39.80
Electrical technician student	0.18	20.75	0.18	21.38	0.80	22.02
		(k\$)		(k\$)		(k\$)
Total Personel	0.71	79.41	0.44	39.75	1.66	143.03
Prototypes/Materials/Softwares		21.25		13.43		45.21
Travel		2.67		2.75		4.68
Radiation Testing Feed						
Final Production						
Shipping						
<b>Total</b>		<b>103.34</b>		<b>55.93</b>		<b>192.92</b>



## Proposed activities FY18

- Develop a preliminary simulation of hit extraction board
- Implement possible design in an evaluation board for further validate
- Provide first estimate of performance and system requirements

## Proposed activities FY19

- Develop a more complete simulation
- Investigate implementation and performance of additional functionalities
- Validate in evaluation boards and possibly incorporate with test stand
- Perform market survey of possible hardware platforms, start to develop system design proposal and cost estimates



## WBS 4.5.9: HEB

	R&D			
Items	FY18		FY19	
	FTE	\$/hr	FTE	\$/hr
	3.00		4.00	
Sr. Engineer	0.50	109.85	0.50	113.15
Sr. Engineer	0.50	109.85	0.50	113.15
Sr. Technician	-	58.49	0.50	60.24
		(k\$)		(k\$)
Total Personel	1.00	195.09	1.50	254.44
Prototypes/Materials/Softwares		5.00		20.00
Travel		10.00		10.00
Final Production				
Shipping				
<b>Total</b>		<b>210.09</b>		<b>284.44</b>





## Proposed activities FY16/17

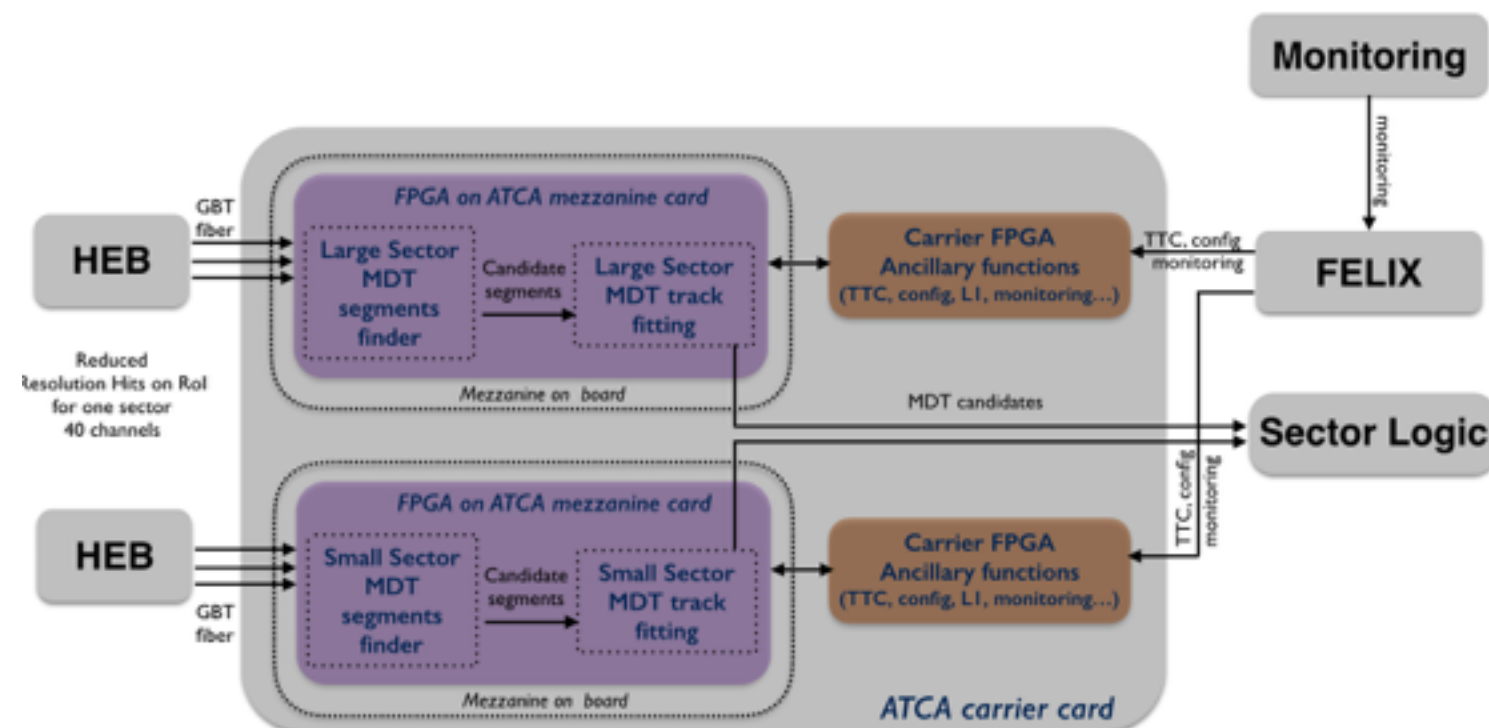
- Develop understanding on how to incorporate MDT at trigger level with simulation
- Evaluate algorithms for segment/track finding & fitting that lead to best trigger efficiency and fake reduction
- Contribute studies for TDR

## Proposed activities FY18

- Refine simulation studies and trigger algorithms
- Develop preliminary simulation of MDT trigger algorithms for hardware
- Implement firmware algorithms on evaluation board. Latency studies.
- Validate firmware against simulation.

## Proposed activities FY19

- Possible integration with test stand
- Carry on algorithm development
- Evaluate best hardware solution
- Start developing design prototype





# R&D Budget - UC Irvine - MDT trigger



## WBS 4.5.10: MDT trigger

	R&D							
Items	FY16		FY17		FY18		FY19	
	FTE	\$/hr	FTE	\$/hr	FTE	\$/hr	FTE	\$/hr
	1.00		2.00		3.00		4.00	
Assoc. Project Sci (TBN)	1.00	80.76	1.00	83.18	1.00	85.68	1.00	88.25
Sr. Engineer	-	98.51	0.25	101.46	1.00	104.51	1.00	107.64
Sr. Technician	-	61.81	-	63.66	-	65.57	-	67.54
Elec. Student	-	24.88	-	25.63	-	26.40	-	27.19
		(k\$)		(k\$)		(k\$)		(k\$)
Total Personel	1.00	143.43	1.25	192.78	2.00	337.76	2.00	347.90
Prototypes/Materials/Softwares		3.89		46.93		5.51		5.67
Travel		9.08		9.36		9.64		9.93
Final Production								
Shipping								
<b>Total</b>		<b>156.40</b>		<b>249.06</b>		<b>352.91</b>		<b>363.50</b>

# Budget Request by WBS: FY16 → FY18



	US WBS		FY16	FY17	FY18	FY19
	R&D					
Mezzanine	4.5.6	Total	-	103.34	55.93	192.92
		FTE	-	0.71	0.44	1.66
		Labor	-	79.41	39.75	143.03
		M&S - Travel	-	23.93	16.18	49.89
FE TDC	4.5.8	Total	-	19.97	344.04	434.90
		FTE	-	0.20	2.50	4.00
		Labor	-	19.97	258.04	425.63
		M&S - Travel	-	-	86.00	9.27
CSM	4.5.7	Total	191.30	249.94	270.20	269.67
		FTE	2.15	2.60	2.60	2.60
		Labor	188.30	241.94	249.20	256.67
		M&S - Travel	3.00	8.00	21.00	13.00
Hit Extraction Board	4.5.9	Total	-	-	210.09	284.44
		FTE	-	-	1.00	1.50
		Labor	-	-	195.09	254.44
		M&S - Travel	-	-	15.00	30.00
MDT Trig Processor	4.5.10	Total	156.40	249.06	352.91	363.50
		FTE	1.00	1.25	2.00	2.00
		Labor	143.43	192.78	337.76	347.90
		M&S - Travel	12.98	56.28	15.15	15.60
Muon		Total	347.70	622.31	1,233.16	1,545.44
		FTE	3.15	4.76	8.54	11.76
		Labor	331.72	534.10	1,079.84	1,427.68
		Core	15.98	88.21	153.32	117.76

# Backup

